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PAPAYA PRODUCTS[1]

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The papaya (Carica papaya), a native of tropical America, superficially resembles a cantaloupe and is sometimes called "tree melon". The excellent flavor and high food value of this fruit have led to its cultivation in most of the tropical and semitropical areas of the world, including nearly frostless localities in Florida, Texas and California (21).

Under favorable growing conditions the herbaceous plants begin to bear in less than a year and may live twenty years and become thirty feet tall. The yields of fruit vary with seed, soil and climatic conditions, and normally decrease after the plants reach an age of three or four years. Individual fruits may vary in weight from one to twenty pounds, but more commonly from two to five.

Papayas are grown commercially from seed (19). Ordinarily the seed has resulted from uncontrolled cross-pollination for many generations of cultivated and wild forms. For the production of uniform fruit of satisfactory flavor, sugar content and shipping quality, the seed must be produced under conditions of controlled pollination from parent stocks that have been selected and bred for the qualities desired.

Papaya plants occur in monoecious, dioecious and intermediate flowering forms. Desirable, perfect-flowered varieties are propagated by self-pollination, repeated for several generations, using seed from selected fruit (16). Dioecious varieties are propagated by sib-pollination, selecting seed from fruit having desirable characteristics (21).

The flavor of properly ripened fruit of selected varieties is excellent. Fruit from unselected seedlings often has poor flavor or shipping quality making it unsuitable for fresh fruit markets. There is considerable normal variation in size and shape of the fruit. Cultivation and frost-protection costs are comparatively high. Profitable production in this country will ordinarily depend upon the utilization, by processing, of sizes and grades of fruit unsuited to fresh markets. Fortunately, various portions of the fruits and plant present interesting by-product possibilities.

The stem and leaves of the papaya contain an alkaloid, carpain, which is used medicinally as a heart stimulant; nevertheless, the tender growing tips are sometimes consumed as greens after boiling in water (6, 18).

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The edible seeds, contained in the center cavity, have a spicy, pungent flavor which has been compared to that of nasturtium and water cress (20). The seeds are reported to have a laxative effect when eaten in quantity. Dried peel and seed residues from processing have been used in poultry feed.

Papain, a proteolytic enzyme, occurs in the latex of the papaya (2) and is recovered for market purposes by scoring the peel of immature fruit attached to the plants and collecting the latex from the surface of the fruit after it has exuded and dried in the air. The fresh fruit or papain is often used by individuals suffering from pepsin deficiency; the papain and latex are also used for tenderizing meat. The quantity of papain in the fruit decreases during ripening, but rubber gloves are nevertheless advisable to protect the hands when peeling and handling ripe fruit.

The proximate composition of the edible flesh of the papaya, according to Stahl (15) is given in Table 1.

Table 1 -- Percentage Composition of the Edible Portion of the Papaya (Fresh Basis)

Moisture	91.0
Acid (as citric)	0.16
Oil	0.45
Protein	0.25
Ash	0.35
Reducing Sugars	5.40
Total Sugars	5.65

The papaya has been reported to contain the equivalent of 2500 I.U./100 g. of vitamin A (11) as caricaxanthin or cryptoxanthin (10) and 34-116 mg./100 g. of vitamin C or ascorbic acid (3).

A number of papaya products are on the market or are in home use. Canned and bottled papaya nectars and soft drinks have been introduced in recent years. Stennis (17) gave recipes for twelve papaya products, including conserve, chutney, pickle and butter. Miller, Bazore and Robbins (10) gave sixteen recipes, including jam, marmalade, catsup and pie. Wolfe and Lynch (21) in a discussion of the uses of the papaya mentioned sweet pickle and crystallized fruit.

Studies of methods for dehydrating the edible portion of the papaya were recently conducted in Florida. The senior author, while located at the U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas, prepared the following promising products: canned blends of papaya pulp and citrus juices; canned slices or cubes of ripe papaya; papaya jam; candied papaya and pickled papaya. The purpose of this paper is to describe experimental methods found most suitable for preparing these products. Dehydrated papaya is probably of the greatest immediate interest because it can be prepared as a good source of vitamins A and C and can readily be eaten as is. Preliminary observations indicate that the low acid and high sugar content of the dried papaya, combined with the candy-like taste and texture, make it suitable for incorporation in concentrated food rations as well as in confections.

Experimental

Analytical Methods. Vitamin C was determined in fresh or blanched papayas by mixing a 25-gram sample for 5 minutes with 200 ml. of extraction solution (0.5% oxalic acid or 2% metaphosphoric acid 8% acetic acid) in a Waring Blendor, filtering with suction after adding filter aid (5, 13), and titrating aliquots of the filtrate with 2,6-dichlorophenolindophenol. The dehydrated papaya was analyzed similarly, samples of 5 grams each being soaked in the extraction solution for 30 minutes before blending. The total volumes of solution for the fresh and dried samples were assumed to be 223 and 200 ml., respectively (9).

Peroxidase in the dehydrated papayas was detected by soaking a 5-gram sample in 200 ml. of water for 30 minutes, blending for 5 minutes, and adding 1 drop of 3% hydrogen peroxide and 3 drops of 1% alcoholic benzidene or guaiacol to 10 ml. of the blended mixture. The appearance within 10 minutes of a blue color with benzidene, or a red color with guaiacol, indicated the presence of peroxidase. Fresh samples were blended with water and tested as above; or the reagents were added directly to the slices. Blanched slices were cut in two and the solutions added to the newly-exposed surfaces (12).

Catalase was detected by adding 3 drops of 3% hydrogen peroxide to 10 ml. of the blended sample prepared as described in the preceding paragraph, and comparing with another 10 ml. portion as a control. The appearance of small gas bubbles was considered a positive test.

Moisture, soluble solids, total sugars (as invert), total acid (as citric) and ash were determined by A.O.A.C. methods (1).

Preparation of the Fruit. Selected Betty and Solo Blue-stem papayas were used for these experiments. In the preparation of the fruit the skin and seeds were removed by the following method: A small disc was cut from the stem end of each fruit to provide a flat surface on which the fruit was rested while most of the peel was removed by downward strokes of a large knife. After all peel remaining was trimmed away, each fruit was halved lengthwise and the seeds and supporting fiber scraped from the center cavity. The weight of the discarded portion varied from 25 to 40% of the total weight of the fruit.

Dehydration of Papaya Slices. A cabinet dehydrator was used in which hot air was blown across the trays at a velocity of approximately 300 feet per minute. The air was electrically heated, with thermostatic control, and the replacement of moist air by fresh was controlled by means of adjustable ports; virtually complete closure of the ports permited total recirculation of the air in the dryer.

Firm, ripe, prepared fruit was quartered and cut transversely into slices 3/8-inch thick, which were spread in a single layer on enameled metal trays. Enzyme inactivation was attempted by heating the slices on trays in the dryer for one hour at 200° F. with total recirculation of the air. The ports were then opened and the drying completed at 155°, the slices being turned over after one hour. The candy-like dried product had an excellent flavor which was retained after storage for several months in air at room temperature. The analysis of a sample of fruit before and after drying is given in Table 2. The pH of the fresh fruit was 5.10.

Table 2 -- Composition of Fresh and Dried Papaya Slices

	Fresh	Dried	Ratio Dried/Fresh
Vitamin C, mg./100 g.	49.0	262	5.3
Moisture, %	91.6	6.2	---
Total Solids, %	8.4	93.8	11.2
Soluble Solids, %	7.13	78.8	11.1
Insoluble Solids, %	1.27	15.0	11.8
Total Sugars (as invert), %	5.21	57.8	11.1
Total Acid (as citric), %	0.15	1.6	10.7
Ash, %	0.53	----	----

Other freshly dehydrated samples contained 214-438 mg./100 g. of vitamin C, 4.8-5.8% moisture, and 62.2-66.7% total sugars. Three samples which had been stored for several months in vacuum-sealed cans contained 297, 147 and 109 mg./100 g. of vitamin C.

Fresh papaya gave strong tests for catalase and for peroxidase by both methods. All dehydrated samples, prepared by the method described, gave positive tests for peroxidase by the benzidene method, though the test was not strong in some samples; tests for peroxidase by the guaiacol method and for catalase were negative.

Sliced papayas 3/8-inch thick were steam-blanched on a galvanized wire screen. After 4 minutes (but not after 3) negative tests were given for catalase and for peroxidase by the guaiacol method; the test for peroxidase by the benzidene method was still positive. The slices after 4 minutes had softened so much that they were difficult to transfer and were leaking badly.

Other slices which were steam-blanched on large watch glasses gave a positive benzidene test for peroxidase after 25 minutes but not after 45 minutes. The condensed water was then poured from the watch glasses, and the fairly soft slices were readily transferred to trays and dried at 155° F. The product contained 153 mg./100 g. of ascorbic acid. This experiment indicates that it may be possible to steam blanch and dehydrate papaya slices on solid trays.

It is uncertain whether papayas should be blanched until the benzident test is negative or only until the guaiacol test for peroxidase or the catalase test is negative. The more vigorous treatment necessary for the former undoubtedly results in a considerable loss of ascorbic acid. Unfortunately, sufficient fruit was not available to carry out storage studies to compare the vitamin C losses and flavor deterioration on fruit dried after various blanching methods.

Dehydration of Papaya Pulp. Since fully ripe papayas may be too soft to slice readily and since complete inactivation of the peroxidase (as indicated by the benzidene method) was difficult, the dehydration of pulped papayas was studied. Prepared quartered fruit was passed through a tapered screw press and then reduced to a smooth paste in a Waring Blender.

The inactivation of peroxidase was first studied. Test tubes half filled with the papaya pulp were immersed in a water bath at the desired temperature and stirred with a thermometer for various periods of time, the final temperature of the pulp being recorded. A portion of the pulp was pipetted from the bottom of each tube and tested for peroxidase by the benzidene method. In this way the minimum time of heating for complete inactivation at 180°, 190°, 200° and 210° F. was determined. The results are given in Table 3.

Table 3 -- Minimum Periods for Inactivation of Peroxidase in Papaya Pulp at Various Temperatures

Temp. of Bath °F.	Time of Heating min.	Final Temp. of Pulp °F.
210	$1\frac{1}{2}$	200
200	$2\frac{1}{2}$	195
190	$3\frac{1}{2}$	190
180	12	180

Five pounds of the prepared pulp was heated with vigorous stirring in a large beaker immersed in boiling water. A benzidene peroxidase test on the pulp was positive at 180° but negative at 185°. As soon as the pulp gave a negative test, it was poured into enameled trays in a layer 3/8-inch thick and dried at 160° for $1\frac{1}{2}$ hours; the caked material was then turned over and the drying completed at 150°. The moisture and vitamin C contents of the original and heated pulps, and of the dehydrated product, are given in Table 4.

Table 4 -- Moisture and Vitamin C Content of Papaya Pulp

Sample	Moisture %	Vitamin C (mg./100 g.) In Sample	Vitamin C (mg./100 g.) Dry Basis	% Retention of Vitamin C
Fresh Pulp	92.5	34.6	461	--
Pulp Heated to 185° F.	91.7	29.0	350	76
Dehydrated Pulp	6.4	219	234	51

Effect of Sub-Freezing Weather on Papayas. One night the temperature in the papaya grove dropped below 29° F. The fruit which subsequently matured was quite inferior in flavor and had lower contents of total solids and sugars.

Canned Blends of Papaya Pulp and Citrus Juices. Cruess, Thomas and Celmer (4) suggested adding citric acid to non-acid fruit and vegetable juices in order to avoid the necessity of processing in pressure retorts. Reid (8) demonstrated the advantages of blending acid citrus juices with carrot and beet juices to produce pulpy blends which could be flash pasteurized in tubular heaters at 210° F. and cooled rapidly after filling and sealing the containers. Most tasters preferred the flash-pasteurized blends to straight vegetable juices which had been retorted at 240° F. Tests by Graham (7) confirmed these observations.

Unless heated to 240° F., thereby causing undesirable changes in flavor, papaya pulp having a pH of about 5.1 must be blended with more-acid juice before canning or bottling in order to avoid spoilage.

During the 1939 season, papaya pulp was blended with citrus juices and canned after flash pasteurization in tubular heaters. Selected ripe Betty papayas, slightly soft to thumb pressure, were peeled and seeded by the method described, and the prepared halves were passed through a tapered screw pulper having 0.027-inch perforations in the screen. The pulp was recirculated through the press until its texture was smooth and uniform. Portions were mixed with equal volumes of orange juice, the acidity of which was 1.2% as anhydrous citrus acid. Other portions were mixed with equal volumes of grapefruit juice, the acidity of which was 1.3% as citric acid. Three percent of sucrose was added to the papaya-orange juice blends and 5% to the papaya-grapefruit juice blends. The blends were flash-heated to 210° in a tubular heater, filled hot, sealed in citrus-enameled cans and in bottles, and cooled. The pH of all blends was below 4.0. Both orange and grapefruit juice blends with papaya pulp were attractive in flavor and appearance and maintained satisfactory quality after 6 months' storage at temperatures ranging from 60° to 95° F.

Blends having acceptable flavor were also prepared by adding sucrose and 20 to 40% of lemon or lime juice to papaya pulp with and without added water. When no water was added, the resulting blends were too thick for direct use as beverages, or for pasteurizing in tubular heaters, making kettle-heating necessary. Dilution of canned juice products with water was considered undesirable (14).

However, the tests showed that beverage bases for use in bottling plants or homes might be prepared from papaya pulp, lemon or lime juice, and sucrose in suitable proportion for dilution. Such bases containing 2% citric acid and 30% soluble solids were prepared and remained satisfactory when stored for over six months at temperatures of 60° to 95° F.

Canned, Sliced and Cubed Papaya. For these products, firm ripe fruit was peeled and seeded by the method which has been described. The fruit used was slightly firmer than that for the papaya pulp blends.

Selected halves were cut into ½-inch cubes and placed in glass containers and in citrus-enameled cans. A 45°-Brix sirup, made by adding sucrose to grapefruit juice, was heated and poured over the cubes. The open containers were exhausted for 30 minutes in hot water at 200° F., sealed, inverted, processed for 15 minutes in a hot water bath and cooled. Both products maintained satisfactory quality for 6 months at 60° to 95° F.

Papaya Jam. Fully ripe fruit, soft to thumb pressure, was peeled and seeded by the method described, and the peeled fruit was crushed in a tapered screw press having ¼-inch perforations in the screen. Red-fleshed papayas (Red Rock) yielded jam with particularly attractive appearance. The following formula was satisfactory:

Papaya pulp	16 lbs.
Lime juice	1 quart
Pectin, 100-grade	2 oz.
Cane sugar	24 lbs.

The pectin, mixed with 2 pounds of the cane sugar, was added to the mixture of pulp and juice which was stirred and heated to boiling. The remaining sugar was then added and the mixture was boiled until it tested 68% soluble solids by refractometer measurement. The preserve or jam was poured hot into glass containers which were then sealed, inverted, and allowed to cool. By omission of the pectin, a sundae topping of excellent flavor was prepared.

Candied Papaya. A method of candying immature papaya fruit was developed and the resulting product, resembling candied citron peel in appearance and flavor, was tested in fruit-cake mix and in mince meat.

Selected well-developed Solo Blue-stem papayas, which were still hard and green, were peeled and seeded by the method described. The quartered fruit was submerged in 4% salt brine, using a weighted wood lattice to hold the fruit below the surface of the brine. After one week the brine was drained and replaced with fresh 4% brine, and the fermentation was allowed to continue for another week. The pickled fruit was then leached in running tap water until it no longer had a salty taste, after which it was boiled in 25% sucrose sirup and allowed to stand overnight. The sucrose content of the sirup was then increased 10% and the mixture was again heated to boiling and allowed to stand overnight. The process was repeated until the sirup tested 72 to 75% solids by refractometer measurement. The translucent, candied fruit was then drained and rolled in powdered sugar.

It was observed that adding sodium bisulfite equivalent of 50 parts per million of sulfur dioxide, to the sucrose sirup before the final boiling aided in preserving the candy under adverse storage conditions without impairing the taste.

Storage tests were continued for longer than a year without apparent deterioration of the candied material. Samples stored for 3 years gradually developed a stale odor and flavor.

Spiced Sweet Papaya Pickle. A sweet spiced papaya pickle was made from the pickled papaya stock, after leaching out the salt, by cutting in small oblong shapes and packing in glass jars, then pouring over it a hot spiced liquor made by the following formula:

Vinegar, 60-grain	1 gal.
Water	1 gal.
Sucrose	16 lbs.
Oil of Clove	0.3 ml.
Oil of Cassia	0.2 ml.
Salt	0.6 oz.

After heating the jars for 45 minutes in a water bath at 180° F., the lids were tightened and the jars were inverted and allowed to cool in air.

Summary

Selected varieties of papayas, because of their delicious flavor, smooth texture, and high content of provitamin A and vitamin C, are excellent as fresh food and are also suitable for processing. Acceptable products have been prepared by dehydration, canning, pickling and preserving. Dehydrated papaya is believed to be suitable for incorporation in confections and in concentrated food rations.

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